U.S. ARMY RDECOM
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

TARDEC

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

TARDEC Ground Vehicle Robotics

Overview Briefing for OESA
10 May 2012

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
10 MAY 2012	**Briefing Charts**	**01-04-2012 to 30-04-2012**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Practical To Tactical: Making the Case for a Shift in Ground Vehicle Robotics	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Jim Overholt	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
U.S. Army TARDEC,6501 East Eleven Mile Rd,Warren,Mi,48397-5000	**#22916**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000	**TARDEC**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)
	#22916

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

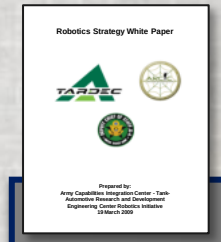
13. SUPPLEMENTARY NOTES
For OESA Technology Forum

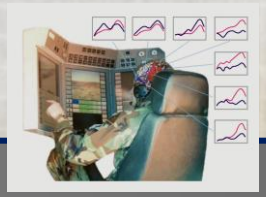
14. ABSTRACT
Soldiers in Small Units (squads/fire teams/crews) are physically overburdened, often carrying up to 130lbs; this degrades performance and may result in immediate, as well as, long term consequences.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Public Release**	**27**	

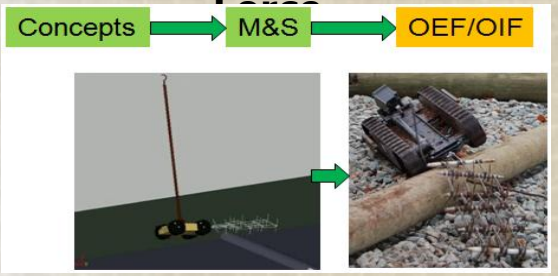
TARDEC Robotics



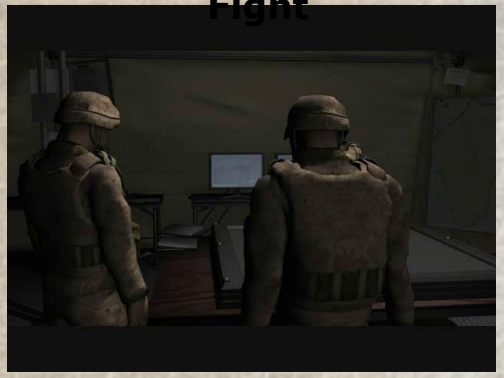


Requirements | Concepts | Analysis | Component Development | Component Testing | System Integration | Virtual Proving Ground | Vehicle Testing/Demo

Supporting the Current Force



Enabling the Future Fight



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Brief History of UGVs

2004
162 systems

- No single vendor could produce 162
- 5 vendors, multiple configurations
- Joint effort, EOD focused

2005
1800 systems

- Robot's proven ability to save lives
- Expansion beyond EOD mission (Countermine, Security)
- Agreements with Rapid Equipping force (REF) and Army material Command (AMC)

2006
4000 systems

- Engineers and Infantry
- Route clearance, Explosive detection & development of robotic weapons payloads

2007
5000 systems

- Special Forces robot applications assessed
- Route clearance, Explosive detection & development of robotic weapons payloads (lethal and non-lethal)

2008
6000 systems

- Maneuver elements
- Range extension
- CBRNE detection
- Persistent surveillance
- More capable payloads

2009-12
Max 10,000 Systems (Current 4,000)

- Batteries – longer life, standardized
- OEF – Mobility
- Limited autonomy
- Weaponization
- Increased agility & dexterity
- Interoperability
- Collaboration

UGVs in the Current Fight

Sustain:
+ Trust and Confidence
+ Reduced Operator Workload
+ Expanded Missions

beyond tele-op

Improve:
- Modularity
- Reliability
- Interoperability
- Collaboration
- Autonomy

Man-Transportable

Micro UGV

Packbot FIDO

Mini EOD

SUGV

Vehicle-Transportable

MDARS

SMSS

MTRS

MK3

Self-Transportable & Appliqué

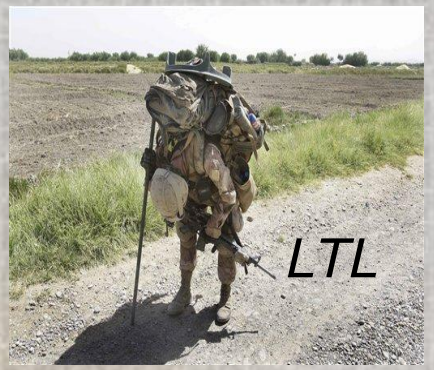
M160 Light Flail

HMDS

SANDI

Ground Robotics Realities

- Robotics benefits…
  - Robots can extend the reach of the soldier
  - Robots can reduce the load of the soldier
  - Robots can go into some dangerous places
  - Robots are better at doing some tasks



- The current realities of **'fielded'** mobile ground robotics…
  - Robots are mostly remotely controlled or tele-operated
  - Robots are difficult to control
  - Robots work best in benign, structured environments
  - Robots are slow and can't keep up with the operation tempo
  - Robots are expensive
  - Robots break down frequently
  - Robots that are 'intelligent' aren't fielded because we can't guarantee their behavior under all conditions
  - **Some soldiers think robots will take their jobs**

Safe Operations & Autonomous Platform Demonstrator (APD)

Safe Ops

'Rules of the Road', structured environments

APD

Off-road mobility, unstructured environments

Enabling Technology Programs

Increased Mobility and Operational Performance through Autonomous Technologies (IMOPAT)

Provide visual local situational awareness (LSA) thru electro-optic indirect vision (EOIV) technologies during manned and unmanned platform operations

Safe Ops of Unmanned Systems for Reconnaissance in Complex Environments (SOURCE)

Autonomous Mobility Appliqué System (AMAS) - JCTD

Distributed Soldier Load Through Robotics for Overburden TECD

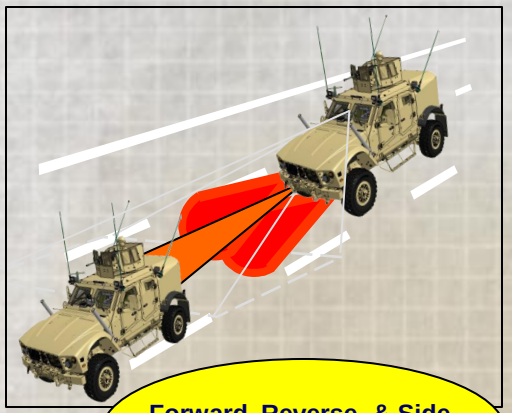
Problem Statement:
Soldiers in Small Units (squads/fire teams/crews) are physically overburdened, often carrying up to 130lbs; this degrades performance and may result in immediate, as well as, long term consequences.

Near term (FY17):
Reduce physical burden of Soldier and Small Unit, including the grenadier, SAW gunner and attached combat medic, so that load reduction of the carried weight equates to a percentage not exceeding 50% of individual's body weight across the central 90% of the male Soldier population.

Occupant Centric Platform TECD Active Safety/Crash Mitigation

OCP Active Safety Demonstrators

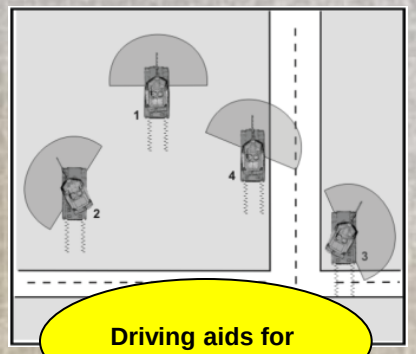
(AMAS-Based Component Set)



Forward, Reverse, & Side Pre-Crash Warning and Collision Avoidance

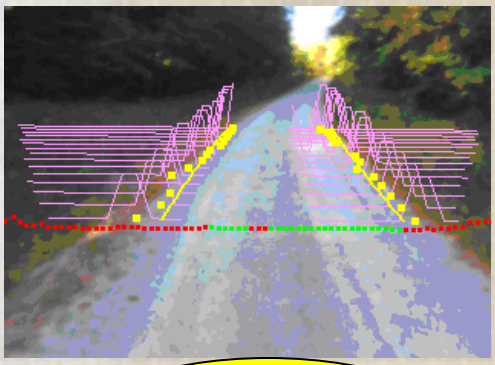
OCP Phase1

OCP Phase 2



Driving aids for Improved Mobility

360° Situational Awareness, Decreased Fatigue, Decreased Collisions and Rollovers, and Improved Vision under all Visibility Conditions.



Unintended Roadway Departure Warning/Prevention

Improved SA and operator workload reduction

Motion Based Cueing for Pop Up/Close-In Target Detection

Provides SA to Soldiers immediately prior to dismount.

Optionally Manned Vehicles

X-by-wire kit

Autonomy kit

Electronic Architecture

Driving functions only

2 modalities

Human in vehicle

(i.e. shared driving)

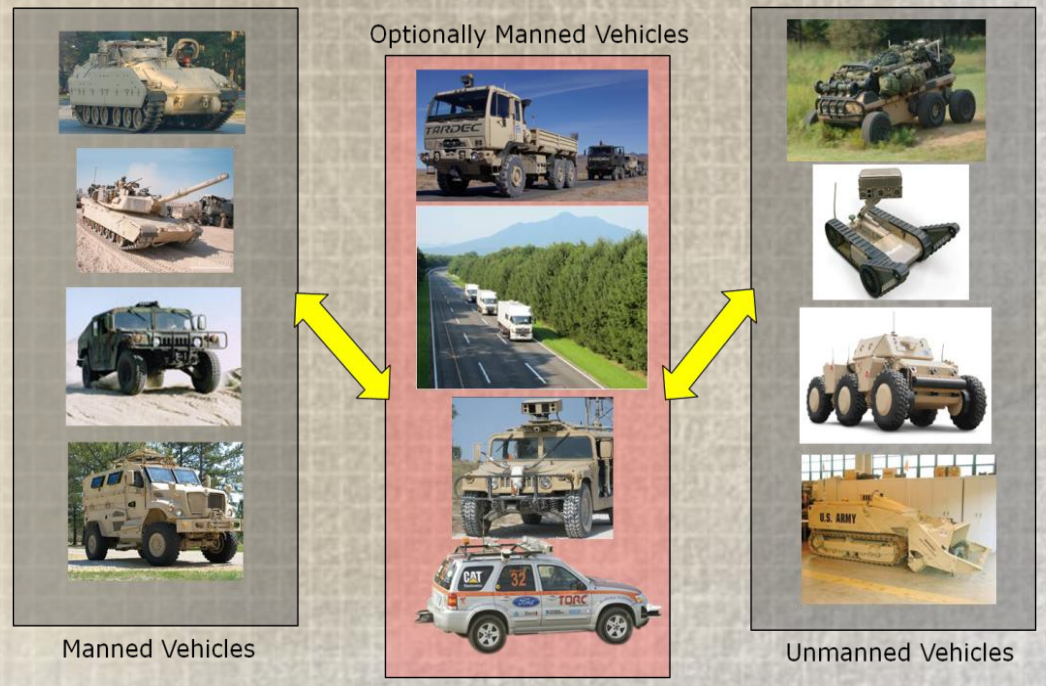
Human NOT in vehicle

(i.e. remotely operated)

invariant across all missions for OMV

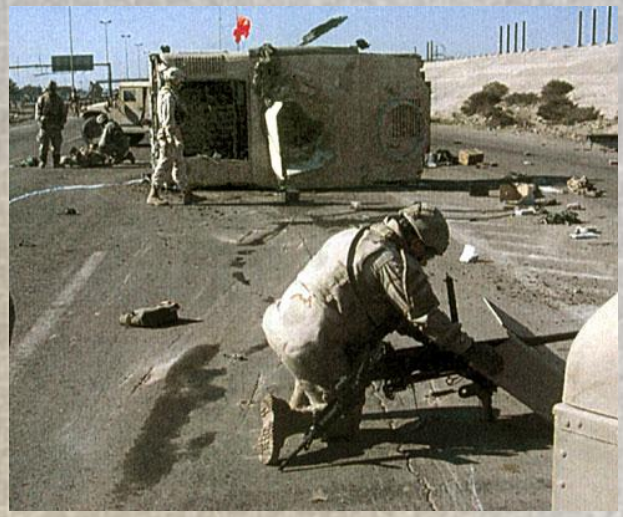
Mission Payloads

OMV can be driven by a soldier;
OMV can drive a soldier;
OMV can be remotely operated;
OMV can be autonomous



Convoy Operations

- Major accidents due to driver error
  - Very long convoy missions—10 to 14 hours
  - Difficult, unpaved, rugged terrain
  - Inexperienced drivers—age 18 & 19 years
  - Collision(Front & Rear), Rollover, Roadway Departure, etc.
- Susceptibility to attack by adversary
  - Asymmetric warfare
    - Improvised explosive devices (IEDs)
    - Coordinated threat attack



Mission Payload Kit

Sensors

Mission Specific Sensors

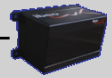
Controls

Mission Specific Software (Processing HW if needed)

Actuators

Mission Specific

General Autonomy/Leader-Follower Kit



Lidar

Common Interfaces

Common Interfaces

Autonomy Computer

GPS Antenna

Communications

By-Wire/Active Safety Kit

Camera

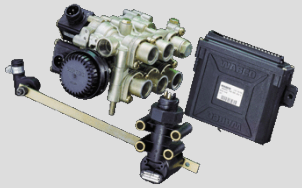
Forward Automotive Radar

Side/Rear Radar x2

Electric Power Assist Steering (EPAS)
Steering Position Sensor Steering Torque Sensor

Gateway Controller

Transmission Controller



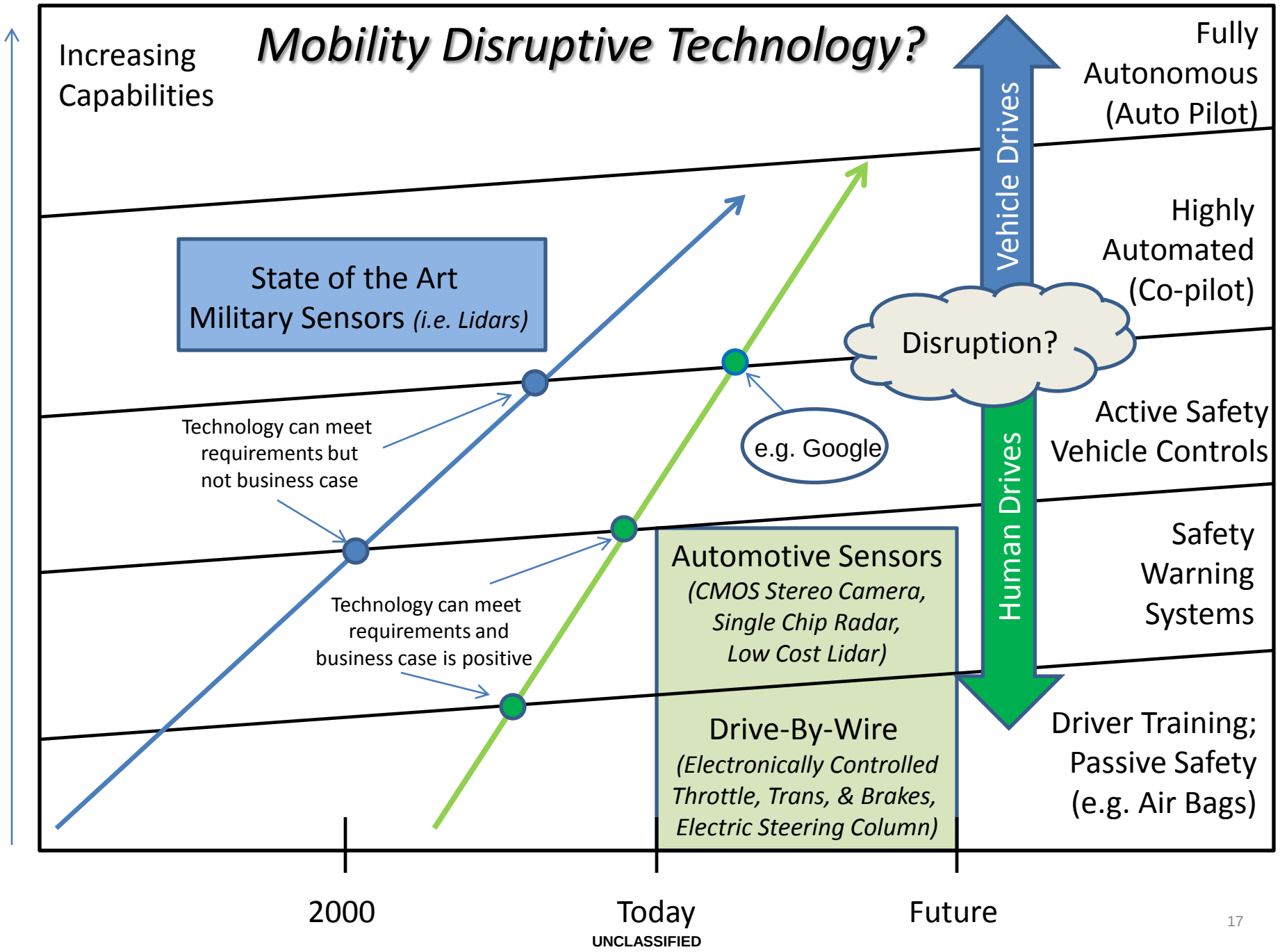
EBS Brake Controller

Wheel Speed Sensors

ESC Accelerometer /Rate Gyro

Engine Controller

UNCLASSIFIED



'Roboticizing' Manned Vehicles

Capability	Description	Man-Vehicle Tasks				Comments
System Off	Current fleet, no intelligence or additional external sensors		Info	Cntr	Rsp	All manned vehicles
		M	x	x	x	
		V				
Driver Warning	Additional sensors being added to monitor activity immediately around Vehicle. Info Task is shared		Info	Cntr	Rsp	Blind-side detectors, collision warning, roll-over warning, V2I and V2V
		M	x	x	x	
		V	x			
Driver Safety	By-wire hardware being added w/ additional sensing. Info task shared and Control task occasionally taken by Vehicle for safety reasons		Info	Cntr	Rsp	At this point, by-wire kit (brake, throttle, gear and steer) is integrated into the vehicle
		M	x	x	x	
		V	x	x		
Optionally Operated (Auto-Pilot)	Human still in vehicle but can 'willingly' give up control so that he/she can perform other tasks (autonomy kit first needed)		Info	Cntr	Rsp	Under certain conditions, 'distracted driving' is the preferred mode of operation
		M	x	x	x	
		V	x	x		
Optionally Manned	All of the previous capabilities plus the additional feature of the vehicle being operated w/o a driver present and a OCU (e.g. convoying, perimeter security)…**AMAS-JCTD**		Info	Cntr	Rsp	Includes emergency modes; Chauffer and Ambulance where I, C and R are Vehicle tasks
		M	x	x	x	
		V	x	x	x	

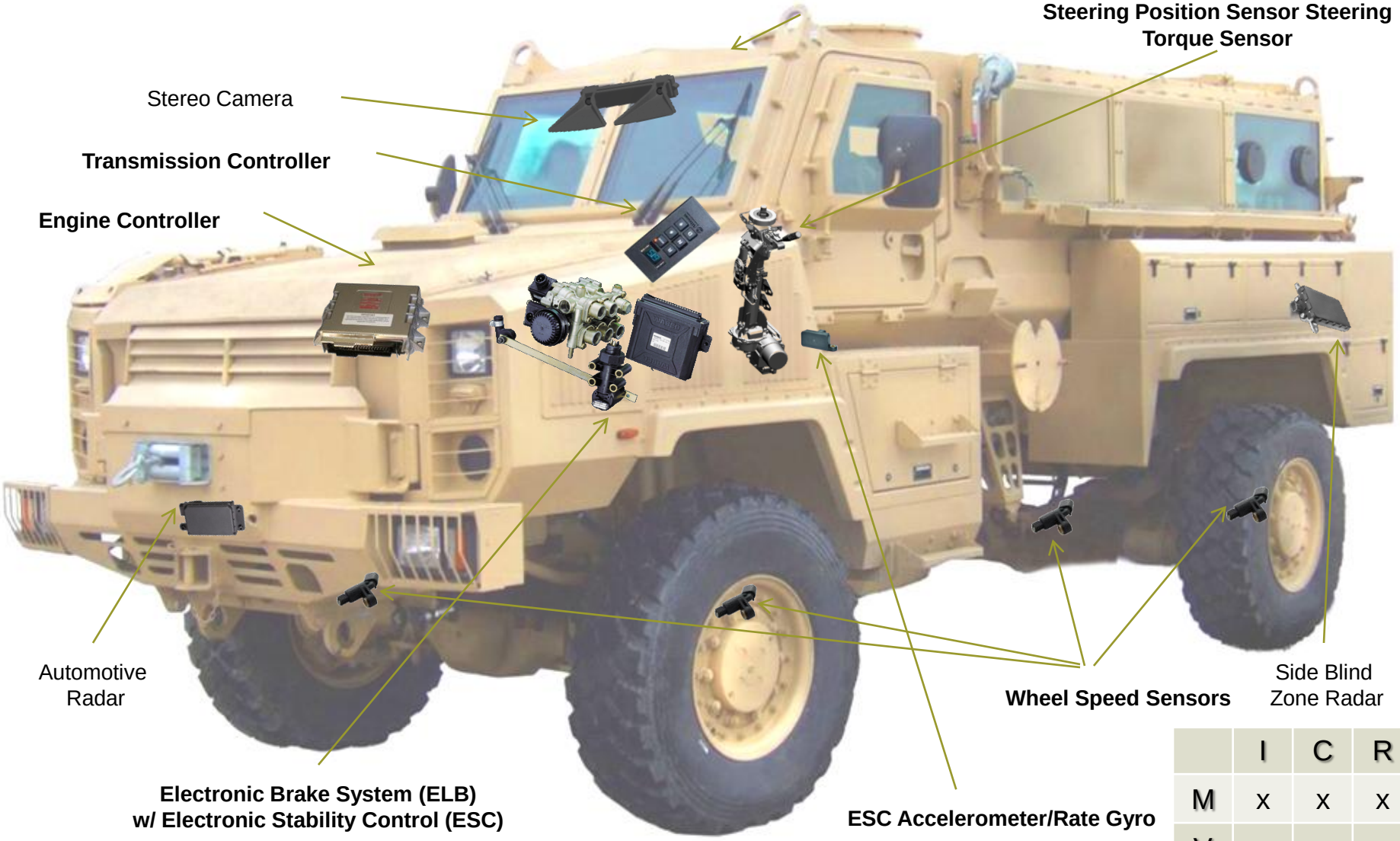
Nominal RG31

	I	C	R
M	X	X	X
V			

RG31 with Driver Warning

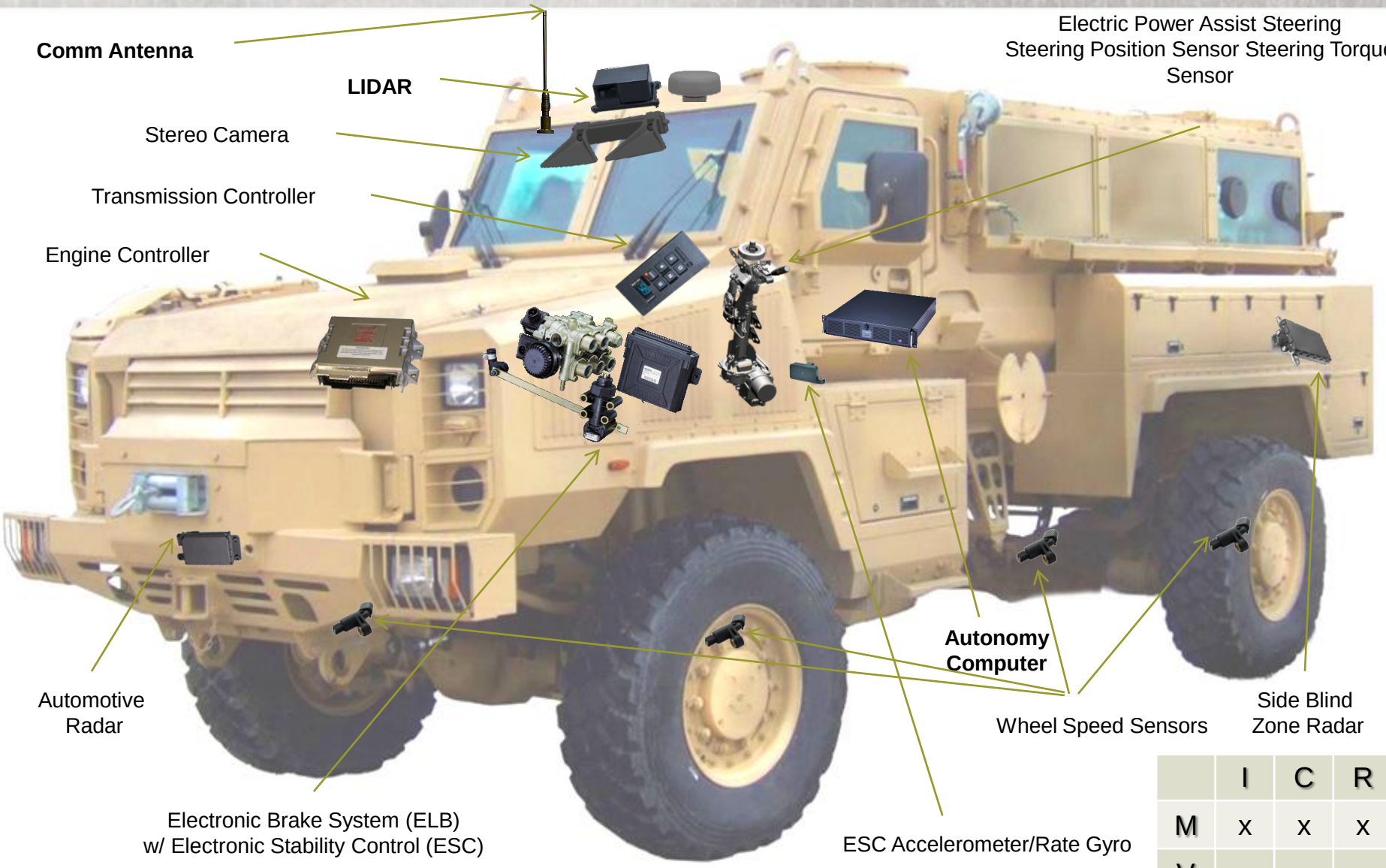
	I	C	R
M	X	X	X
V	X		

RG31 with Active Safety



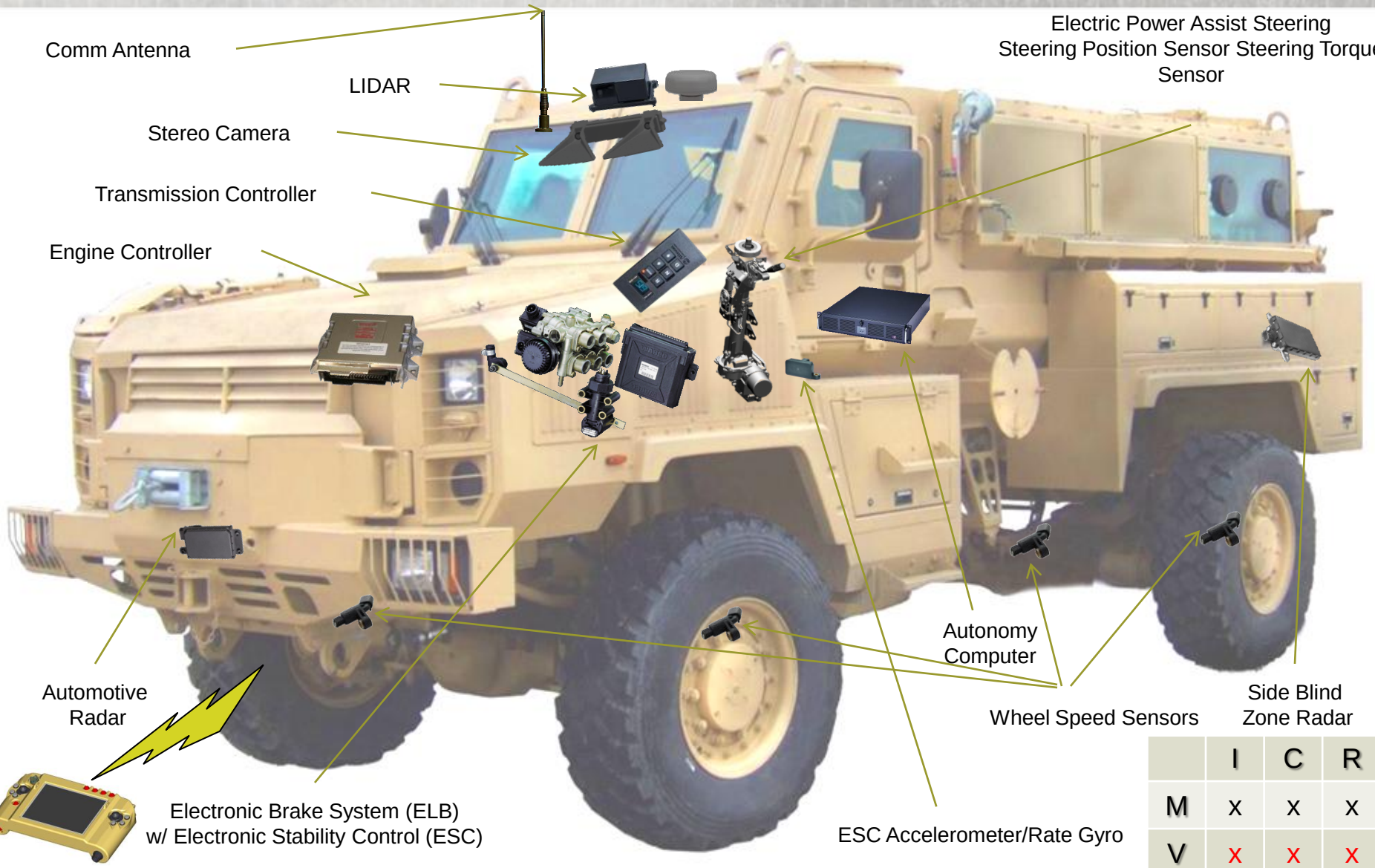
	I	C	R
M	X	X	X
V	X	X	

RG31 – Optionally Operated



	I	C	R
M	X	X	X
V	X	X	

RG31 – Optionally Manned



	I	C	R
M	x	x	x
V	x	x	x

UGV Risk Matrix

RISK Acceptance Levels per DODI 5000.02, 8 Dec 08 Risk Assessment Levels & Definitions per Tables A-I thru A-IV of MIL-STD 882D, 10 Feb 00					HAZARD SEVERITY			
					Catastrophic	Critical	Marginal	Negligible
		Specific Individual Item	Fleet or Inventory		Could result in death, permanent total disability, loss exceeding $1M, or irreversible severe environmental damage that violates law or regulation.	Could result in permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, loss exceeding $200K but less than $1M, or reversible environmental damage causing a violation of law or regulation.	Could result in injury or occupational illness resulting in one or more lost work days(s), loss exceeding $10K but less than $200K, or mitigatible environmental damage without violation of law or regulation where restoration activities can be accomplished.	Could result in injury or illness not resulting in a lost work day, loss exceeding $2K but less than $10K, or minimal environmental damage not violating law or regulation.
					1	2	3	4
HAZARD PROBABILITY	Frequent	Likely to occur often in the life of an item, with a probability of occurrence greater than 10^{-1} in that life.	Continuously experienced	A	1-A HIGH AAE	2-A HIGH AAE	3-A SERIOUS PEO	4-A MEDIUM PM
	Probable	Will occur several times in the life of an item, with a probability of occurrence less than 10^{-1} but greater than 10^{-2} in that life	Will occur frequently	B	1-B HIGH AAE	2-B HIGH AAE	3-B SERIOUS PEO	4-B MEDIUM PM
	Occasional	Likely to occur some time in the life of an item, with a probability of occurrence less than 10^{-2} but greater than 10^{-3} in that life	Will occur several times	C	1-C HIGH AAE	2-C SERIOUS PEO	3-C MEDIUM PM	4-C LOW PM
	Remote	Unlikely but possible to occur in the life of an item, with a probability of occurrence less than 10^{-3} but greater than 10^{-6} in that life	Unlikely, but can reasonably be expected to occur	D	1-D SERIOUS PEO	2-D MEDIUM PM	3-D MEDIUM PM	4-D LOW PM
	Improbable	So unlikely, it can be assumed occurrence may not be experienced, with a probability of occurrence less than 10^{-6} in that life	Unlikely to occur, but possible	E	1-E MEDIUM PM	2-E MEDIUM PM	3-E MEDIUM PM	4-E LOW PM

Emphasize Controllability

Hazard Analysis and Risk Assignment

- ASIL (Automotive Safety Integrity Level)*

Severity		Exposure		Controllability	
S0	No injuries	E1	Very low probability	C0	Controllable in general
S1	Light and moderate injuries	E2	Low probability (<1%)	C1	Simply controllable (>99% of drivers)
S2	Severe injuries (survival probable)	E3	Medium probability (1%~10%)	C2	Normally controllable (>90% of drivers)
S3	Life-threatening injuries	E4	High probability (>10%)	C3	Difficult to control (<90% of drivers)

		C		
S	E	C1	C2	C3
S1	E1	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	ASIL A
	E4	QM	ASIL A	ASIL B
S2	E1	QM	QM	QM
	E2	QM	QM	ASIL A
	E3	QM	ASIL A	ASIL B
	E4	ASIL A	ASIL B	ASIL C
S3	E1	QM	QM	ASIL A
	E2	QM	ASIL A	ASIL B
	E3	ASIL A	ASIL B	ASIL C
	E4	ASIL B	ASIL C	ASIL D

SAE International™

* From ISO 26262

PAPER #2011-01-2357

Variables We Can't Control

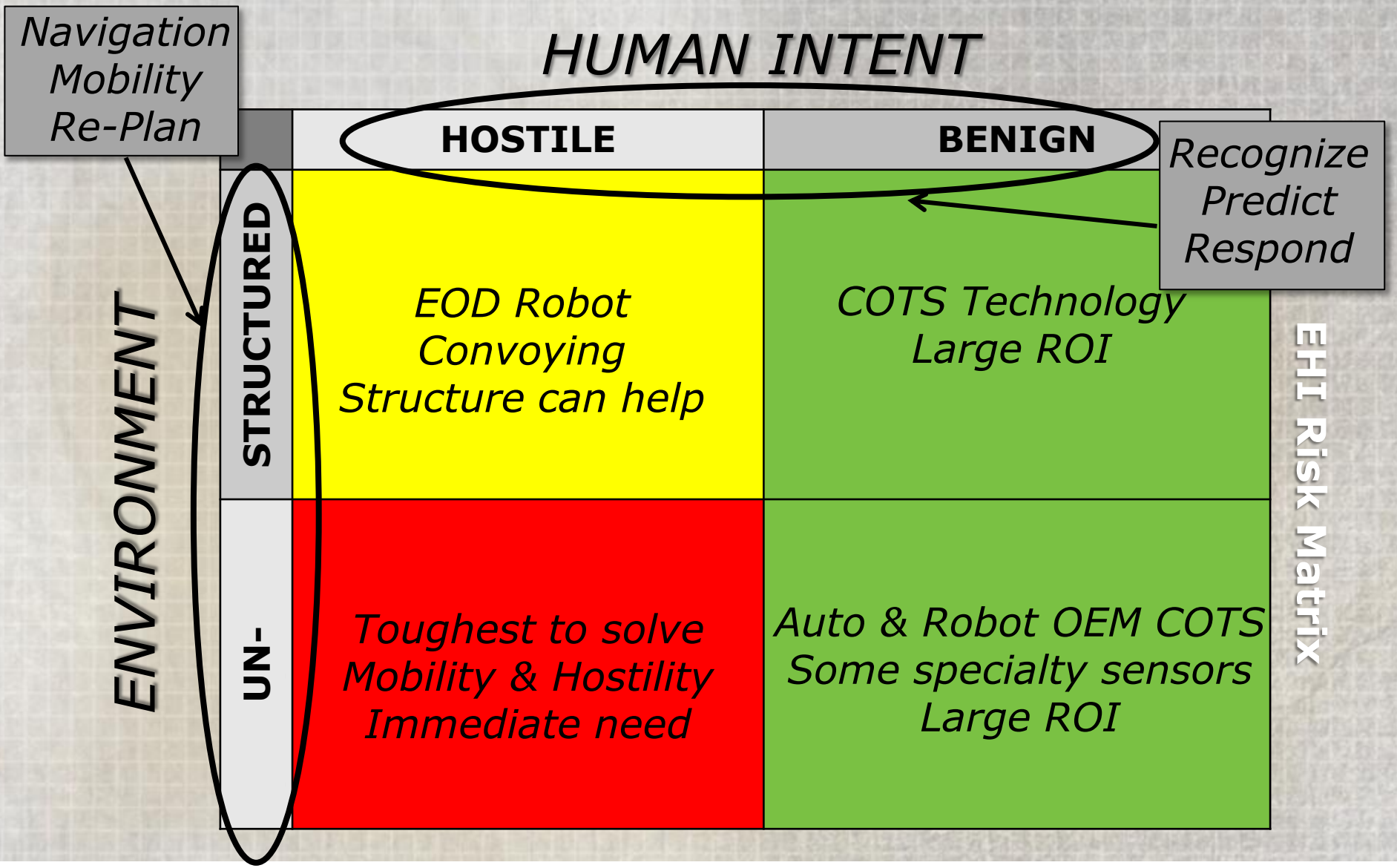
- ENVIRONMENT…
  - **Structured** vs. **Un-Structured**
  - Structured includes road-ways, upright buildings, military bases
  - Un-structured includes x-country, rubble, dense forest/jungle, snow, rain, fog,…
  - In general, no roads/hallways = un-structured
  - Radiation, deep ocean, deep space, etc…
- HUMAN INTENT…
  - **Benign** vs. **Hostile**
  - Benign; Humans generally don't mean to do intentional harm
  - Generally follow the 'rules of the road'
  - Stupid behavior
  - Hostile; Humans intend to inflict mayhem
  - Humans don't generally follow the 'rules of the road'
  - Legacy or Live engagements
  - *Identify/Recognize/Response hierarchy*








Low 'Cost' of Entry



Robotic Missions

Recognize
Predict
Respond

HUMAN INTENT

ENVIRONMENT	HOSTILE	BENIGN
STRUCTURED	• Convoying (fuel/H_2O) • Convoying (maneuver) • **Base security** • **Check point inspection** • **EOD** • **C-IED/Route Clearance** • Persistent surveillance	• **Convoying (e.g. CONUS)** • **Logistics warehousing** • Sea-basing • **Transportation** • **Base security**
UN-	• **Disaster Clean-Up** • **Engineering** • **EOD** • **C-IED** • **RSTA** • Persistent surveillance • Wingman	• **Range clearance** • **Soldier training** • **Decoys** • **Mining** • Natural disasters (e.g. Hurricane Katrina) • Rescue robotics

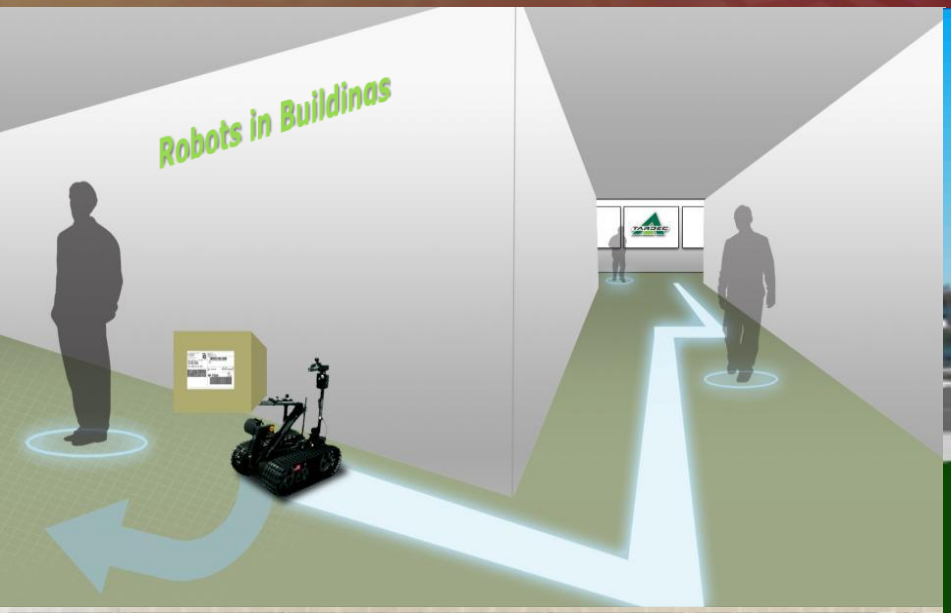
6.1/6.2 S&T Challenges

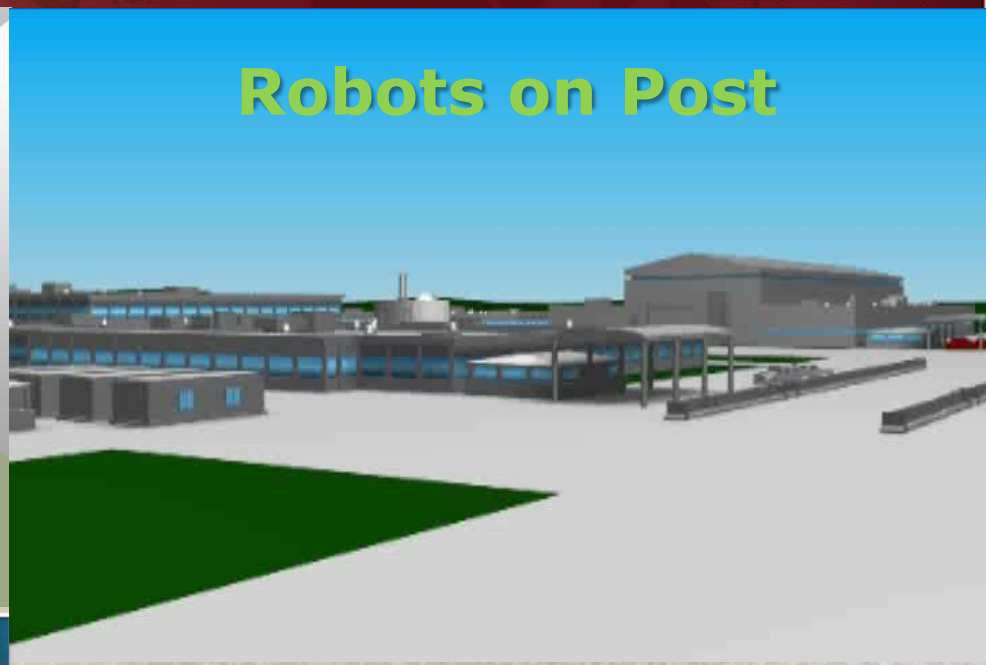
*Current Missions in **BOLD***

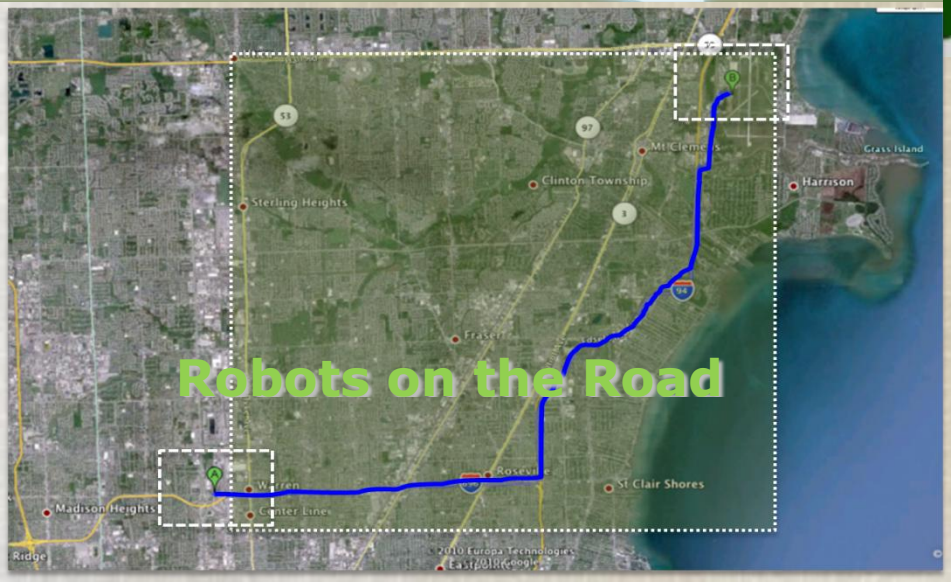
COTS Technology
Large ROI

EHI Risk Matrix

UGV Living Laboratory







ARIBO

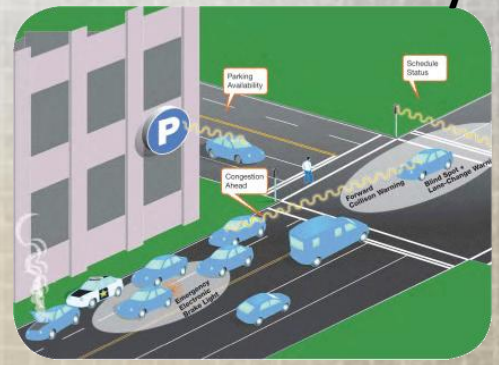
Autonomous Robotics for Installation & Base Operations

-Transportation
-Protection
-Logistics

'New' Partners

Automotive Safety Sensors

Automotive Industry



Wireless V-to-X communications

Automatic Platooning Systems

New Sensor Designs

Computer Industry

High Performance GPUs

New Players in Autonomy


TWVS ATO
GLASS CERAMIC
TRANSPARENT ARMOR
TARDEC
HERMIT
TARDEC

Questions?